Particle-Size Analysis

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Learning objectives

- Review sedimentary particle textures
- Know Udden-Wentworth grain size scale and Phi (ϕ) scale, and the relationships between the two
- Know how to plot grain size data: histograms; frequency curves; cumulative frequency curves
- Know how to obtain grain size data
- Understand grain size descriptive statistics
  - Mode
  - Median
  - Graphic estimation of mean
  - Phi standard deviation (graphic estimation of sorting)
  - Graphic skewness

Sedimentary textures

Textural properties of siliciclastic sediments and rocks include:

1. Grain size
2. Sorting
3. Grain shape
    1. Rounding
    2. Sphericity
4. Particle surface textures
5. Grain fabric

Grain size scales

Udden-Wentworth scale

- **Geometric scale** in which each step is twice as large as the previous one
- **Range** is from 1/256 mm to >256 mm
- Four major **size classes** are
  - Gravel (> 2.00 mm)
  - Sand (1/16 mm to 2.00 mm)
  - Silt (1/256 mm to 1/16 mm)
  - Clay (< 1/256 mm)

(Silt and Clay: mud)

Grain size scales (continued)

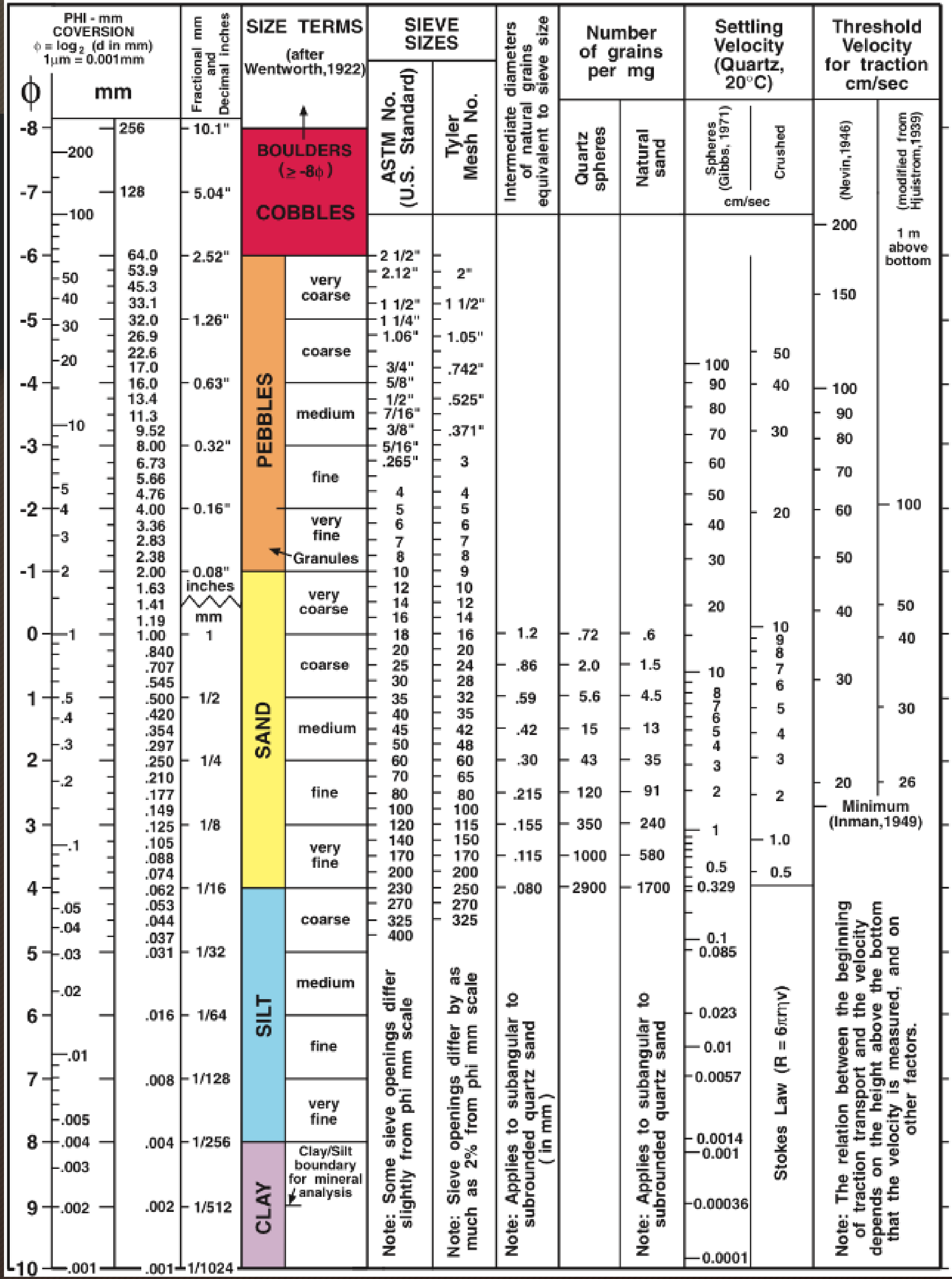
- **Phi scale (Krumbein)**
  - Logarithmic scale useful for plotting and statistical calculations

$$\Phi = -\log_2 d$$

(where *d* = grain diameter, in mm)

Note that 1.00 mm = 0ϕ
Φ increases with smaller grain size,
decreases with larger grain size

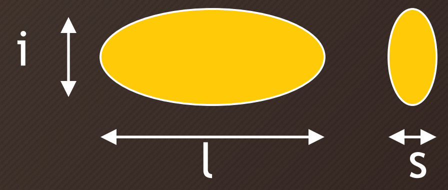
Handout



Wentworth grain size chart from United States Geological Survey Open-File Report 2006-1195

Measuring grain size

- **Technique** for measuring grain size depends on:
  - Purpose of study
  - Size range of material being measured
  - Consolidated vs. unconsolidated
- Grain size is usually expressed in terms of **long dimension** or **intermediate dimension** of particle



Measuring grain size (continued)

Type of sample	Sample grade	Method of analysis
Unconsolidated sediment and disaggregated sedimentary rock	Boulders Cobbles Pebbles	Manual measurement of individual clasts
	Granules Sand Silt	Sieving, settling-tube analysis, image analysis
	Silt Clay	Pipette analysis, sedimentation balances, photohydrometer, Sedigraph, laser-diffractometer, electro-resistance (e.g., Coulter counter)
Lithified sedimentary rock	Boulders Cobbles Pebbles	Manual measurement of individual clasts
	Granules Sand Silt	Thin-section measurement, image analysis
	Silt Clay	Electron microscope

Measuring grain size (continued)

Sieving is useful for unconsolidated material ranging from granule to silt size

- Sieve screen catches particles according to intermediate dimension

Petrographic microscope with ocular micrometer is useful for lithified sand and silt sized material

- Actual measurements or visual comparison with known standards
- Measurements tend to underestimate actual size because grain axes rarely lie in plane of thin section

Graphical treatment of grain size data

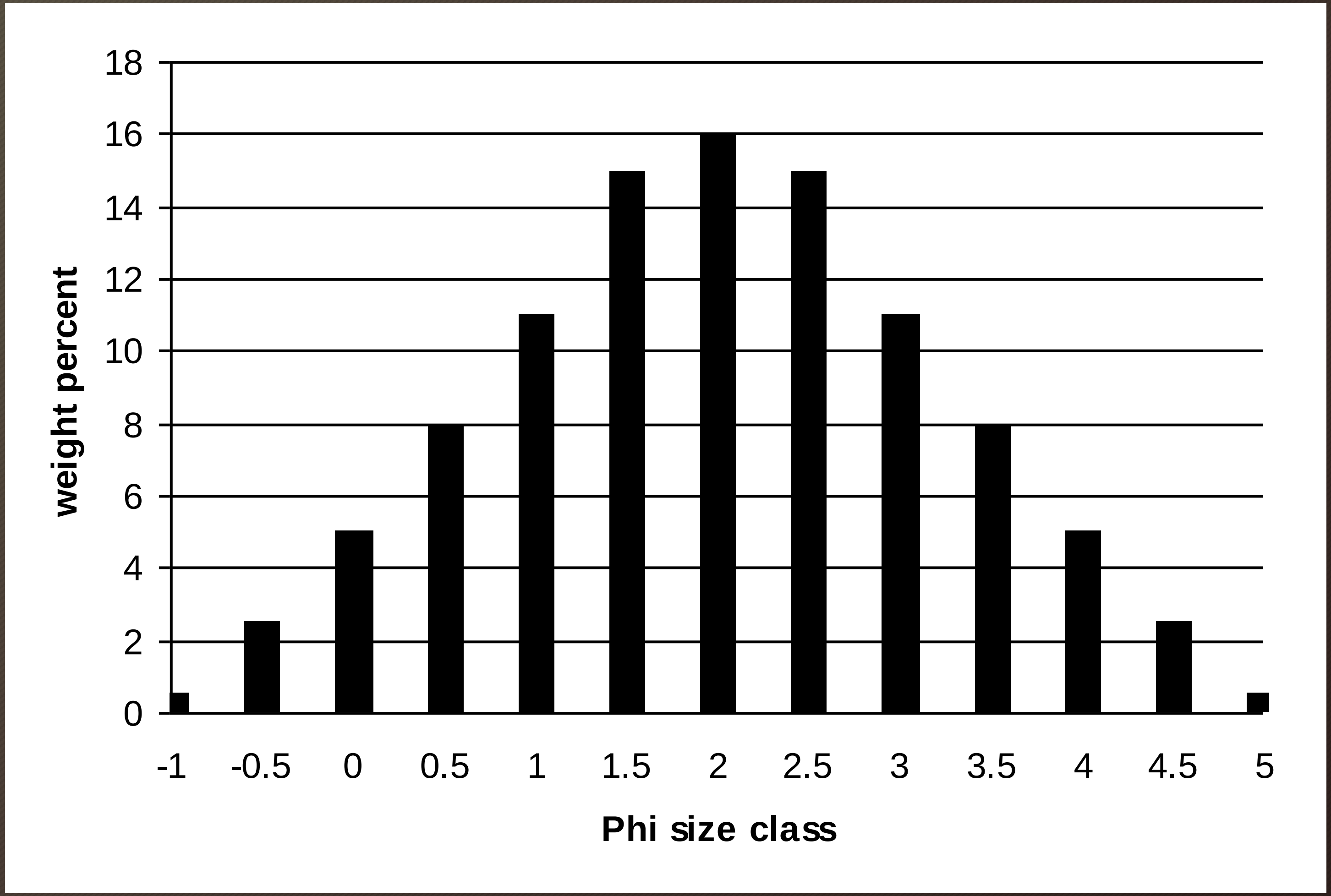
Common graphical methods for presenting grain size data are:

- **Histogram**
  - Individual weight percent is plotted for each ϕ size class
- **Frequency curve**
  - A histogram in which a smooth curve connects the midpoints of each size class
- **Cumulative curve**
  - A plot of ϕ grain size versus cumulative weight percent
  - Most useful for estimating statistical parameters

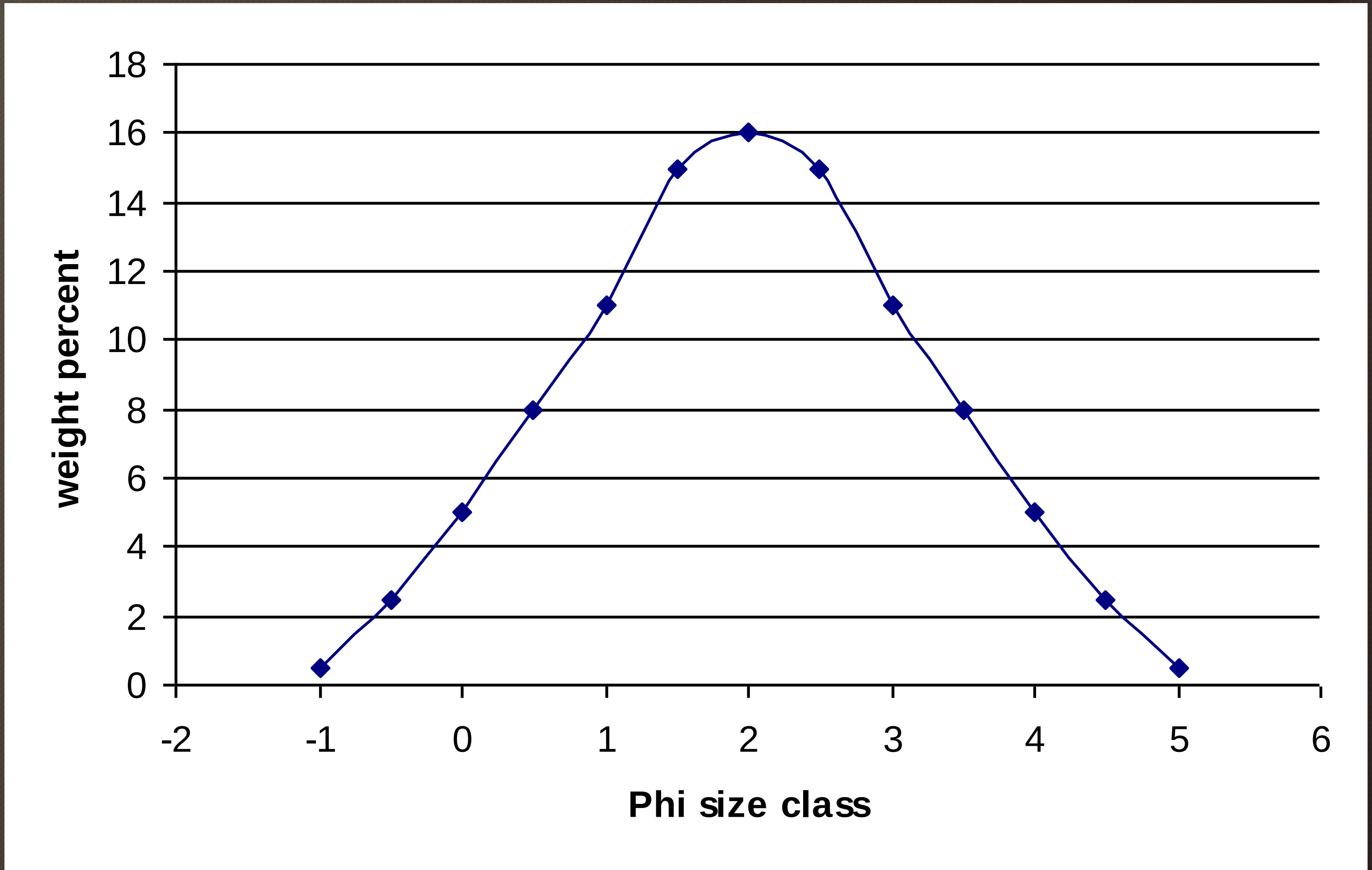
Graphical treatment of grain size data

ϕ size class	raw weight (gm)	individual weight percent	cumulative weight percent
-1.00	0.39	0.50	0.50
-0.50	1.96	2.50	3.00
0.00	3.92	5.00	8.00
0.50	6.26	8.00	16.00
1.00	8.61	11.00	27.00
1.50	11.75	15.00	42.00
2.00	12.53	16.00	58.00
2.50	11.75	15.00	73.00
3.00	8.61	11.00	84.00
3.50	6.26	8.00	92.00
4.00	3.92	5.00	97.00
4.50	1.96	2.50	99.50
5.00	0.39	0.50	**100.00**
total	**78.3**		

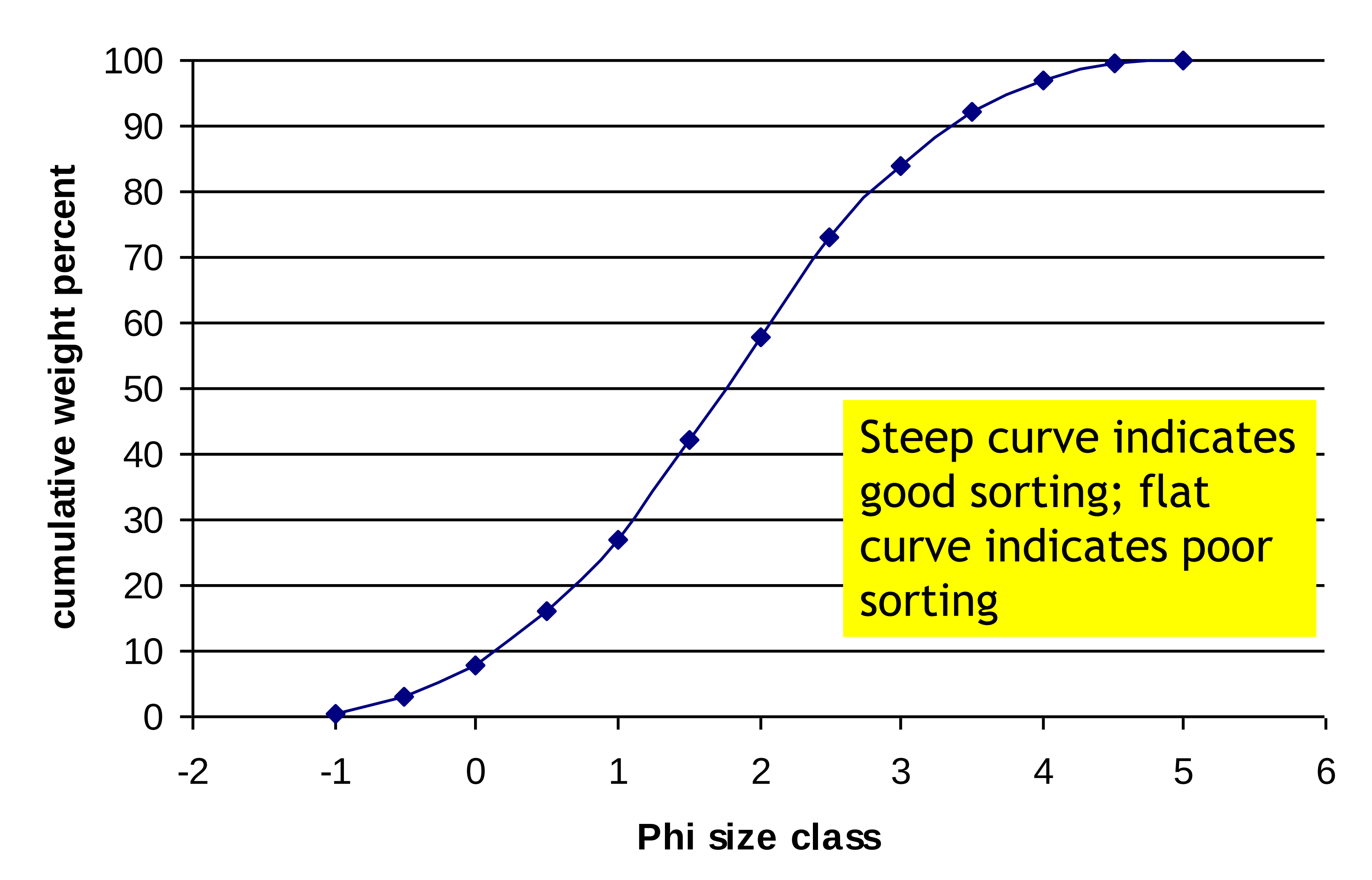
Histogram


18
16
14
12
10
8
6
4
2
0
weight percent
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Phi size class

Frequency curve



Cumulative curve



Grain size statistics

<u>Mode</u> = the most frequently occurring particle size in a population of grains

- Highest point of a frequency curve or histogram; steepest segment of a cumulative curve

<u>Median</u> = midpoint of grain size distribution

- 50th percentile on cumulative curve

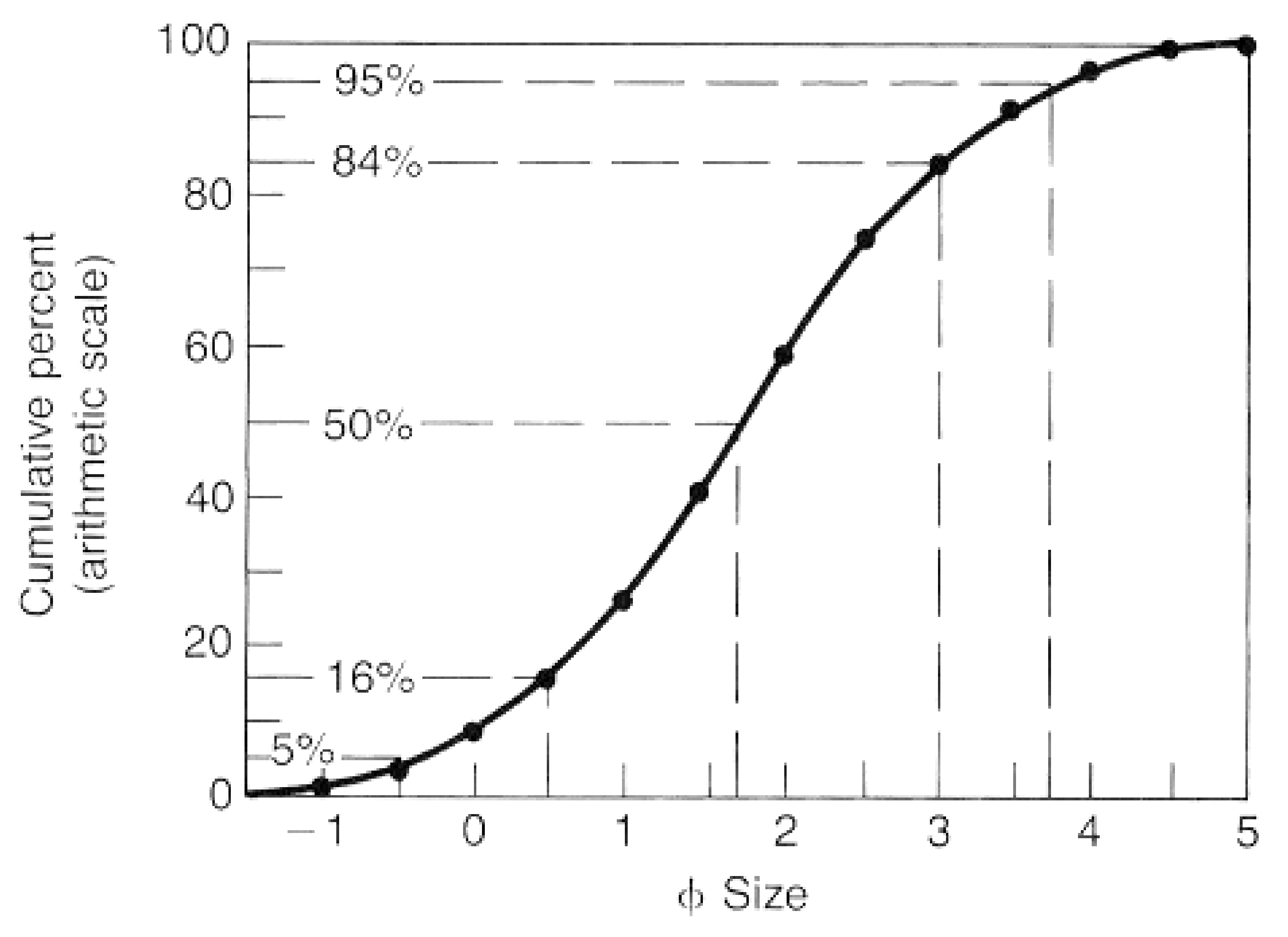
<u>Mean</u> = arithmetic average grain size

- Practically impossible to determine
- Can be approximated graphically

Mean = median = mode in a perfectly normal distribution; ***<u>but</u>***, most natural samples are not normally distributed!

Determining the **graphic mean** particle size:

$$M_Z = \frac{[\phi_{16} + \phi_{50} + \phi_{84}]}{3}$$

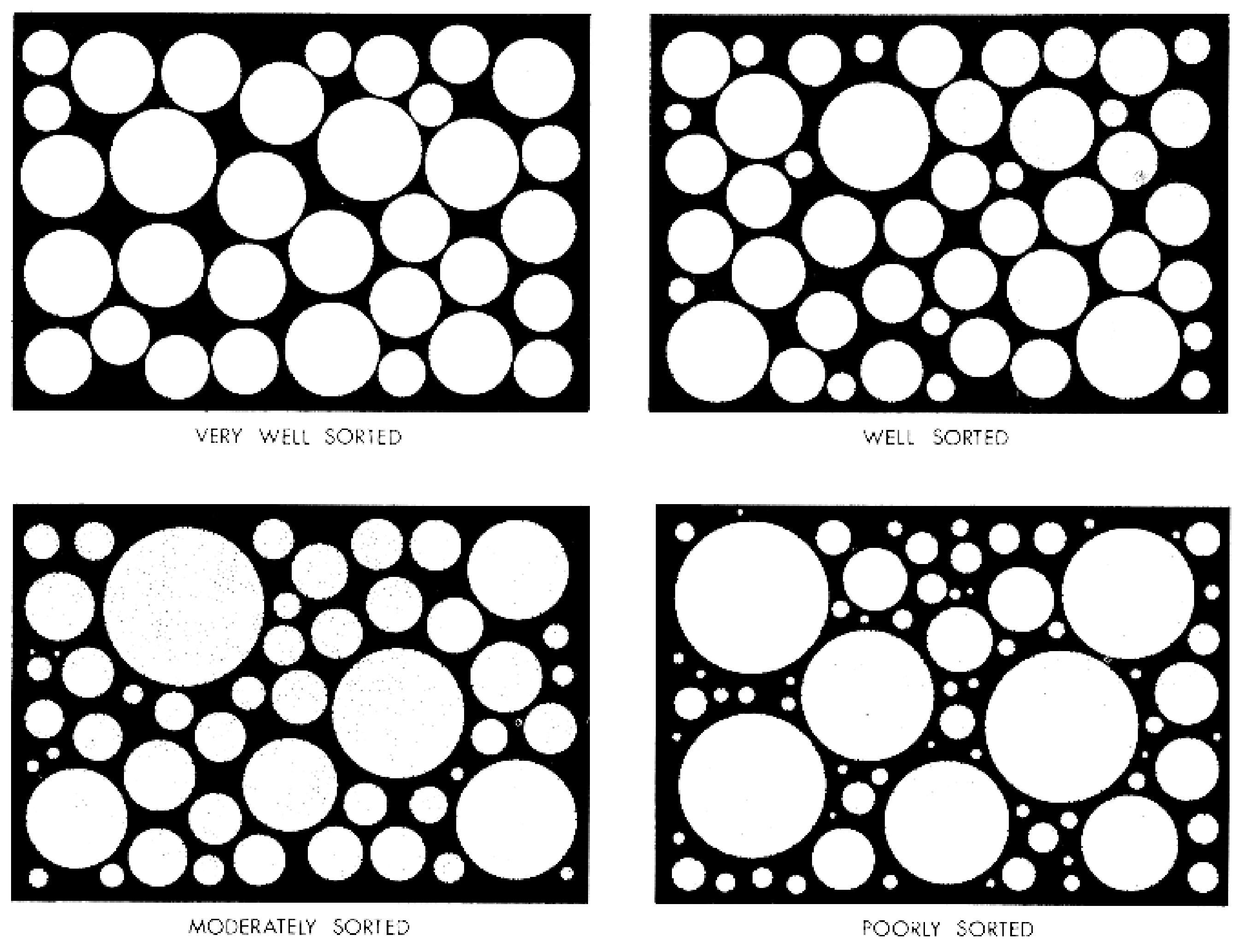


Sorting

Sorting is a measure of the **range of grain sizes** present in a population and the magnitude of the **scatter of those sizes around the mean size**

Sorting can be estimated by **visual comparison** with known standards or by **graphic calculations**

Visual estimation of sorting

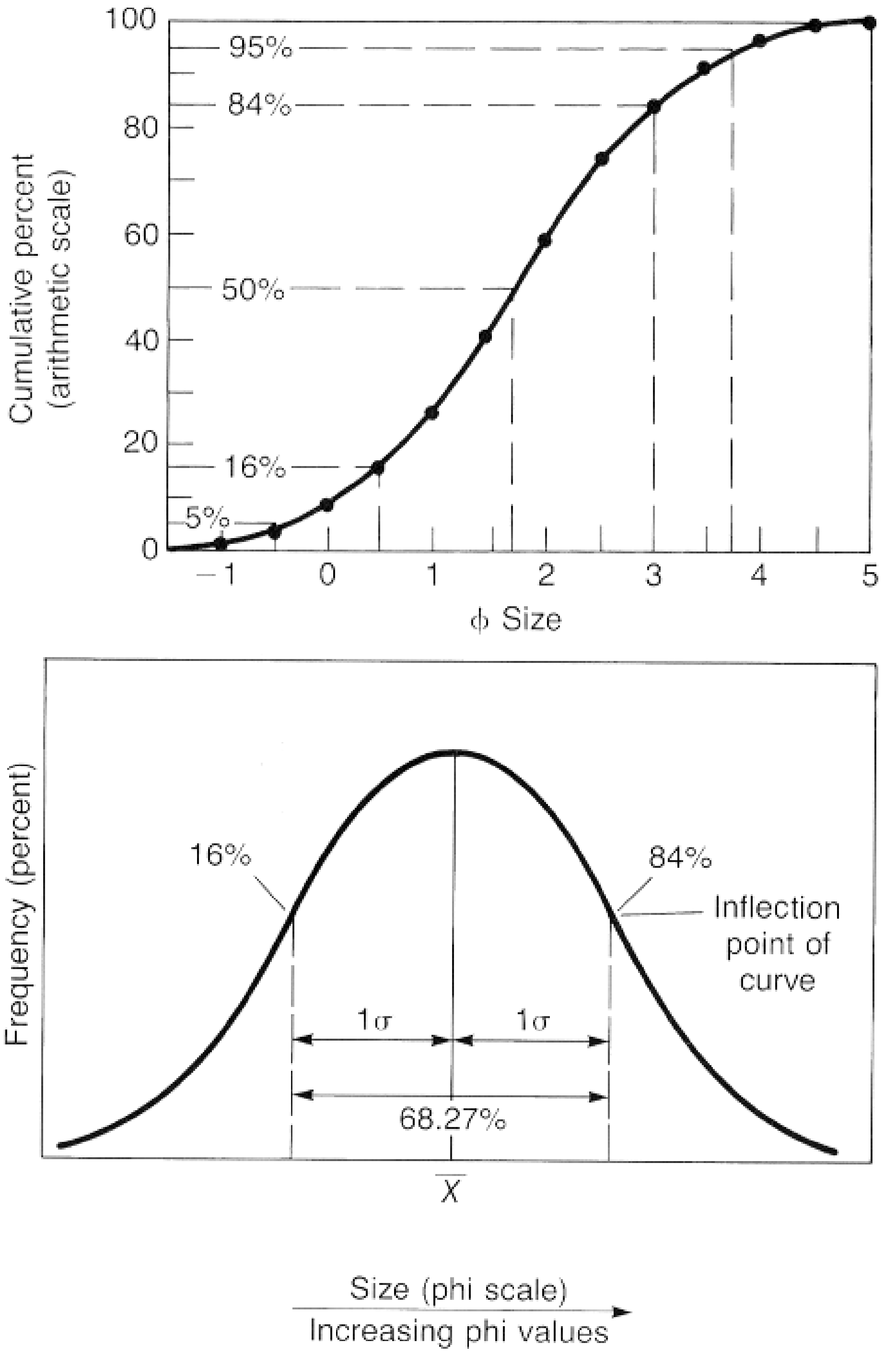


Graphic estimation of sorting

$$\sigma_i = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

Phi standard deviation

< 0.35ϕ = very well sorted
0.35-0.50ϕ = well sorted
0.50-0.71ϕ = moderately well sorted
0.71-1.00ϕ = moderately sorted
1.00-2.00ϕ = poorly sorted
2.00-4.00ϕ = very poorly sorted
> 4.00ϕ = extremely poorly sorted



Application and importance of grain size data

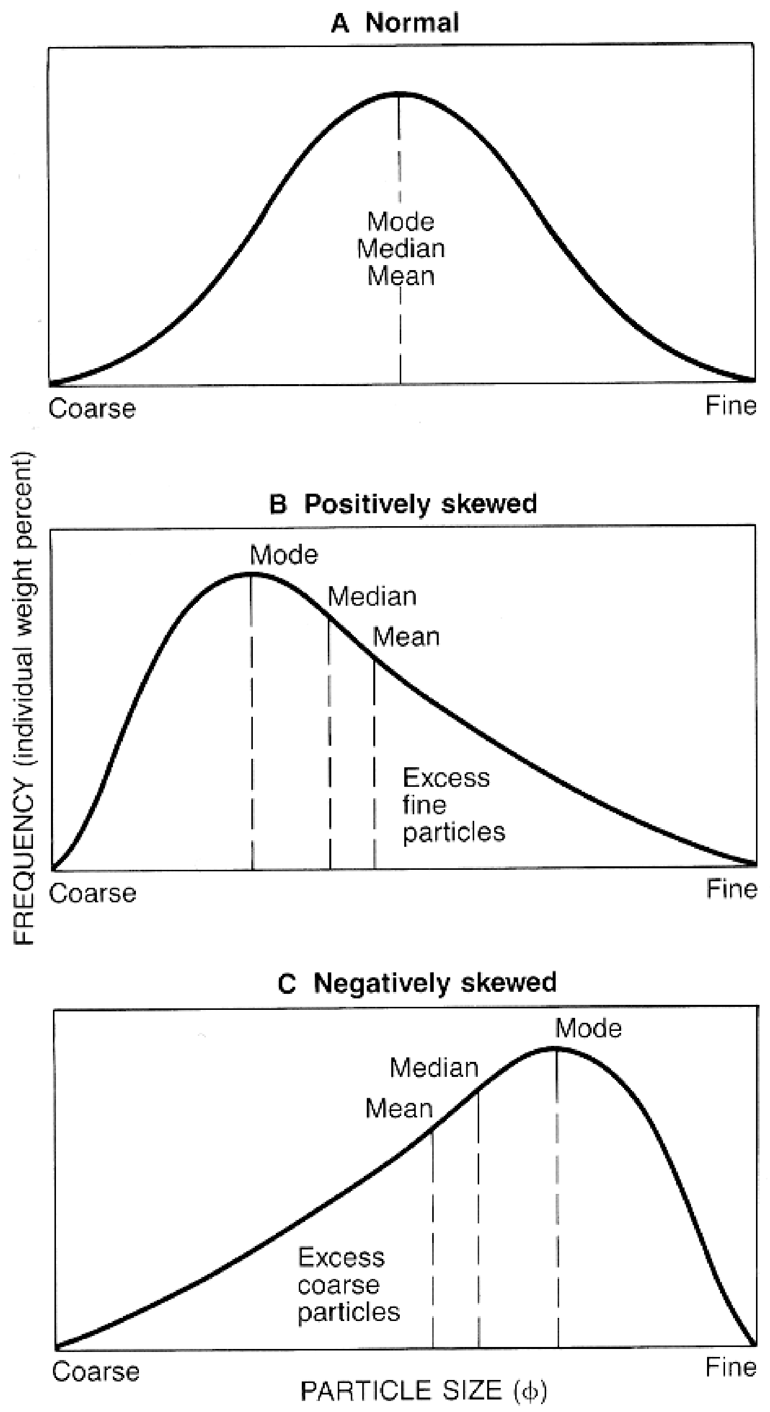
Grain size is most useful as a descriptive property insofar as it relates to the derived properties

- porosity and permeability

Grain size, in and of itself, is not a reliable indicator of depositional environments because the grain size distribution of a sediment is the **result of processes not environments, but it may infer the energy present**

- i.e., sediment transport processes are not unique to any given environment

Skewness = a measure of the amount of departure from a normal distribution (i.e., an asymmetrical frequency curve)



Graphical estimation of skewness

$$SK_i = \frac{\phi_{84} + \phi_{16} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{95} + \phi_5 - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

Graphic skewness

>0.30	strongly fine skewed
0.30 to 0.10	fine skewed
0.10 to -0.10	nearly symmetrical
-0.10 to -0.30	coarse skewed
< -0.30	strongly coarse skewed

Stoke’s Law

$$V = \frac{(\rho_s - \rho_f)gR^2}{18\mu}$$

V = terminal velocity

P_s = Mass density of particles (kg/m^3)

P_f = Mass density of fluid (kg/m^3)

μ = Viscosity of water (kg/m*s)

g = gravitational acceleration (m/s^2)

D = diameter of sphere

- Note that if the particle and the fluid have identical densities, no settling will occur.
- Stoke’s Law is valid only for particles smaller than 0.2mm